MODERN GRID
STRATEGY

What is the Smart Grid?

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Objective Today

To share a common view on what constitutes a Smart Grid:

- **Its values**
- **Its fundamental characteristics**
- **Its key technology areas**
- **A pathway for getting there**
- **The need for metrics**

What is the role of the MGS?

- Define a vision for the Modern Grid
- Reach out to stakeholders to gain consensus
- Assist in the identification and resolution of barriers & issues
- Act as "independent broker" consistent with the vision
- Promote testing of integrated suites of technologies
- Communicate success stories to stimulate deployment

Our role is Strategic rather than Tactical!

Background

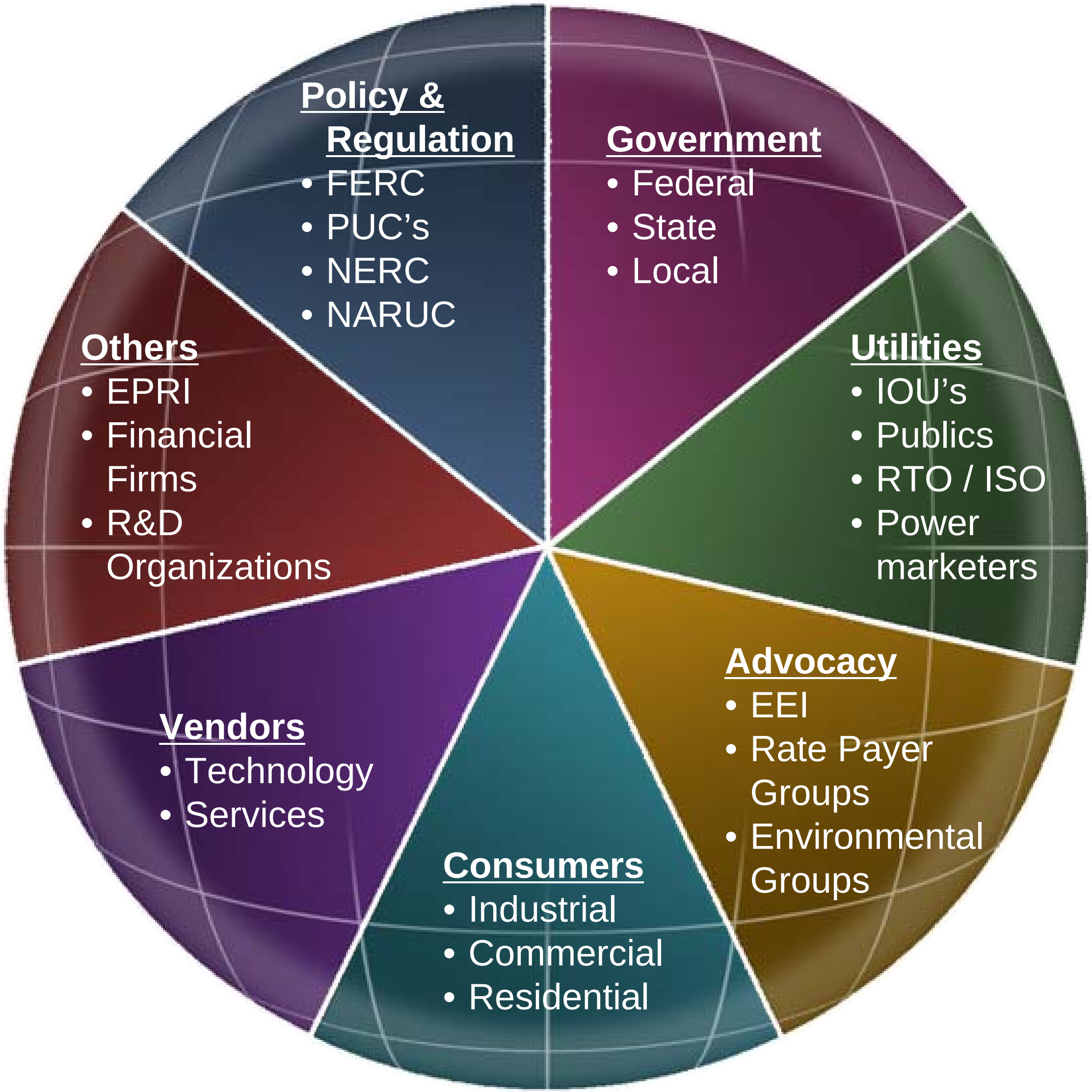
NETL's Modern Grid Strategy

- Began concept development in early 2005
- Conducted regional summits (7) to get input
- Numerous other presentations
- Incorporated feedback

Smart Grid Workshop

- Further unification of concepts with others
- Workshop planned for June 2008 with focus on metric development

Who are the Smart Grid stakeholders?



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Why Modernize the Grid?

- Today's grid is aging and outmoded
- Unreliability is costing consumers billions
- Today's grid is vulnerable to attack and natural disaster
- An extended loss of today's grid could be catastrophic to our security, economy and quality of life
- Today's grid does not address the 21st century power supply challenges
- The benefits of a modernized grid are substantial

Running today's digital society through yesterday's grid is like running the Internet through an old telephone switchboard.

Reid Detchon, Energy Future Coalition

Smart Grid Values

The Smart Grid is MORE:

- **Reliable**
- **Secure**
- **Economic**
- **Efficient**
- **Environmentally friendly**
- **Safe**

These values define the goals for grid modernization and suggest where metrics are needed to monitor progress.

Smart Grid Characteristics

The Smart Grid will:

- Enable active participation by consumers
- Accommodate all generation and storage options
- Enable new products, services and markets
- Provide power quality for the digital economy
- Optimize asset utilization and operate efficiently
- Anticipate & respond to system disturbances (self-heal)
- Operate resiliently against attack and natural disaster

Smart Grid Characteristics

It will "Enable active participation by consumers"

- **Customers see what they use, when they use it, and what it costs**
- **Consumers have access to new information, control and options**
  - Manage energy costs
  - Invest in new devices
  - Sell resources for revenue or environmental stewardship
- **Grid operators have new resource options**
  - Energy and capacity
  - Ancillary services

Involving the consumer is win – win!

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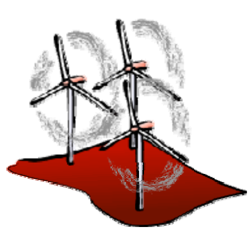
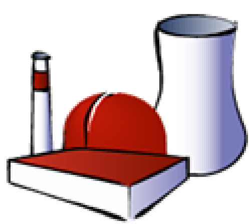
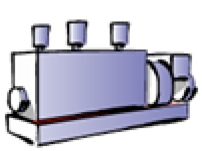
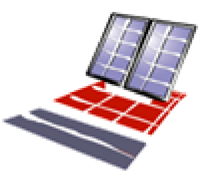
Smart Grid Characteristics

It will "Accommodate all generation and storage options"

- Seamlessly integrates all types and sizes of electrical generation and storage systems
- Simplified interconnection process analogous to "plug-and-play"
- Large central power plants including environmentally-friendly sources such as wind and solar farms and advanced nuclear plants will continue to play a major role
- Number of smaller, decentralized sources will increase

Smart Grid Characteristics

It will "Enable new products, services and markets"

- Links buyers and sellers down to the consumer level
- Supports the creation of "secondary" electricity markets
  - Brokers, integrators, aggregators, etc.
  - New commercial goods and services
- Provides for consistent market operation across regions
- Supports growth of competitive retail markets
- Stimulates deployment of energy resources closer to the consumer

Markets motivate behavior and get results!

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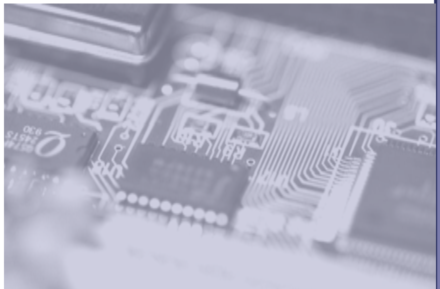
It will "Provide power quality for the digital economy"

- Monitors, diagnoses and responds to PQ issues
- Varying grades of power quality at different pricing levels
- Power quality standards will balance load sensitivity with delivered power quality at a reasonable price
- Solutions at both system and consumer level

Voltage dips that last less than 100 milliseconds can have the same effect on an industrial process as an outage that lasts several minutes or more

Primen, 2002



Smart Grid Characteristics

It will "Optimize asset utilization and operate efficiently"

- Improved load factors and lower system losses
- More power through existing systems
- The knowledge to build only what we need
- Tools for efficient, optimized designs
- Intelligent monitoring and diagnostics
- Computer-aided asset management, workflow management, outage management
- Condition Based Maintenance

Convergence of operating information with asset management processes will dramatically improve grid efficiency

Smart Grid Characteristics

It will "Anticipate & respond to system disturbances (self-heal)"

- Performs continuous self-assessments
- Detects, analyzes, responds to, and restores grid components or network sections
- Handles problems too large or too fast-moving for human intervention
- Acts as the grid's "immune system"
- Supports grid reliability, security, and power quality

The blackout of August 2003 took hours to build up. Once it breached the original service territory, it took 9 seconds to blackout 50M people.

PNNL, June 2006

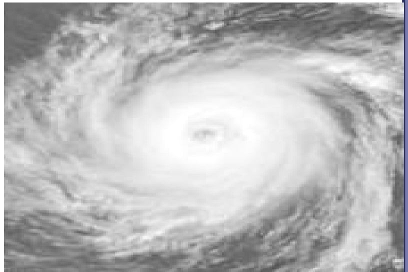
Smart Grid Characteristics

It will "Operate resiliently against attack and natural disaster"

- Physical and cyber security built in from the ground up
- Reduces threat, vulnerability, consequences
- Deters, detects, mitigates, responds, and restores
- Less vulnerable to natural disasters
- Energy security has become national security

The lack of a concerted, deliberate technical approach risks serious consequences from security threats to the power delivery system infrastructure.

Erich Gunther, Power & Energy Continuity, 2002



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The Smart Grid Gap

Characteristic	*Today*	*Tomorrow*
Enables Consumer Participation	Little price visibility, time-of-use pricing rare, few choices	Full price info, choose from many plans, prices and options, buy and sell
Accommodates Generation/Storage	Dominated by central generation. Little DG, DR, storage or renewables.	Many "plug and play" distributed energy resources complement central generation
Enables New Markets	Limited wholesale markets, not well integrated	Mature, well-integrated wholesale markets, growth of new electricity markets
Meets PQ Needs	Focus on outages not power quality	PQ a priority with a variety of quality/price options according to needs

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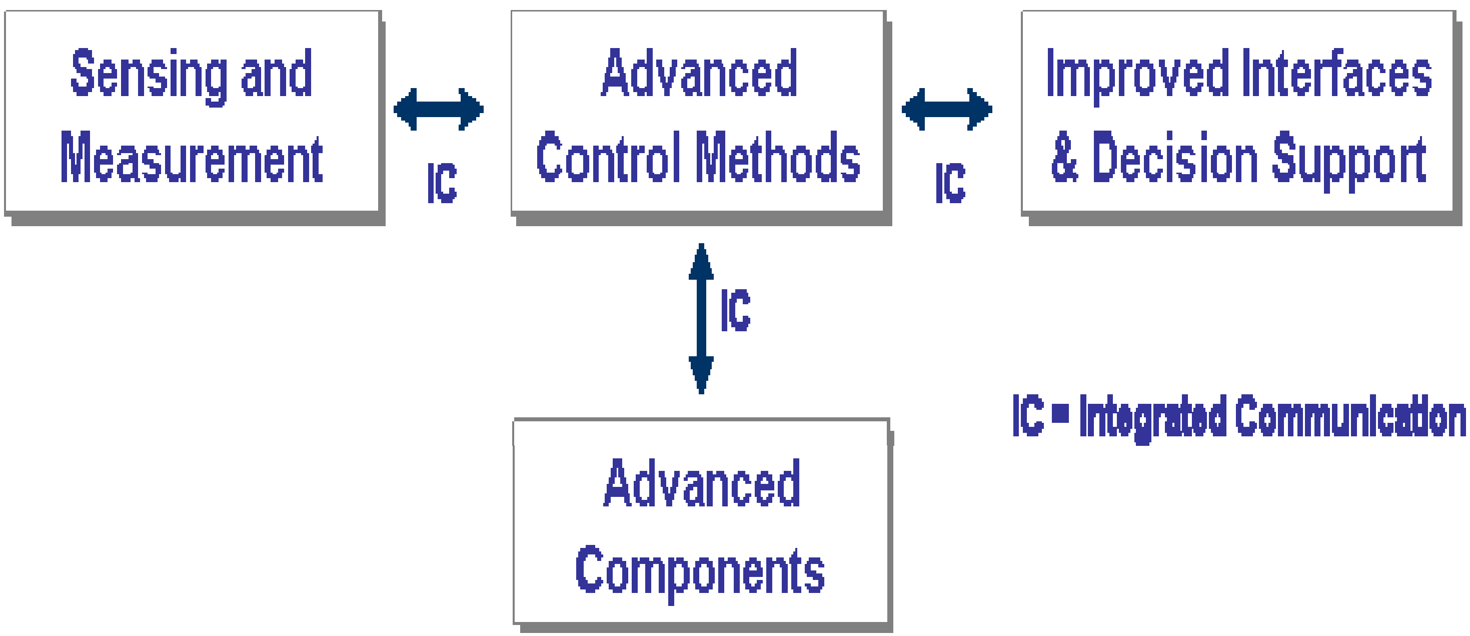
The Smart Grid Gap

Characteristic	*Today*	*Tomorrow*
Optimizes Assets & Operates Efficiently	Little integration with asset management	Deep integration of grid intelligence with asset management software
Self Heals	Protects assets following disruption (e.g. trip relay)	Prevents disruptions, minimizes impact, restores rapidly
Resists Attack	Vulnerable to terrorists and natural disasters	Deters, detects, mitigates, and restores rapidly and efficiently

Smart Grid Key Technologies



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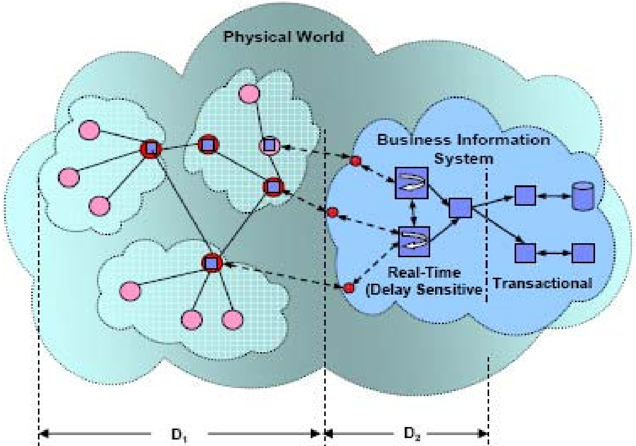
Integrated Communications

An effective, fully-integrated communications infrastructure is an essential component of the Smart Grid:

- IC creates a dynamic, interactive "mega-infrastructure" for real-time information and power exchange
- IC allows the various intelligent electronic devices (smart meters, control centers, power electronic controllers, protection devices) and users to interact as an integrated system



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Sensing and Measurement

Some examples:

- Smart meters
- Ubiquitous system operating parameters
- Asset condition monitors
- Wide area monitoring systems (WAMS)
- Advanced system protection
- Dynamic rating of transmission lines

Advanced Control Methods

Broad application of computer-based algorithms that:

- Collect data from and monitor all essential grid components
- Analyze the data to diagnose and provide solutions from both deterministic and predictive perspectives
- Determine and take appropriate actions autonomously or through operators (depending on timing and complexity)
- Provide information and solutions to human operators
- Integrate with enterprise-wide processes and technologies

Advanced Components

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Some Examples:

- Next generation FACTS/PQ devices
- Advanced distributed generation and energy storage
- PHEV
- Fault current limiters
- Superconducting transmission cable & rotating machines
- Microgrids
- Advanced switches and conductors
- Solid state transformers

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Decision Support

- Data reduction
- Visualization
- Speed of comprehension
- Decision support
- System operator training

How do we get there?

Modern Grid Milestones

- **Advanced Metering Infrastructure *(AMI)***
- **Advanced Distribution Operations *(ADO)***
- **Advanced Transmission Operations *(ATO)***
- **Advanced Asset Management *(AAM)***

Each Milestone requires the deployment and integration of various technologies and applications

AMI Technologies

- **Smart Meters**
- **Two-way Communications**
- **Consumer Portal**
- **Home Area Network**
- **Meter Data Management**
- **Demand Response**
- **Customer Service Applications**
- **Operational Gateway Applications**

AMI empowers the customer and supports grid operations

ADO Technologies and Applications

- Distribution Management System with advanced sensors
- Advanced Outage Management (“real-time”)
- DER Operations
- Distribution Automation
- Distribution Geographic Information System
- Micro-grid operations (AC and DC)
- Advanced protection and control
- Advanced grid components for distribution

The functionality of ADO enables “Self Healing”

ATO Technologies and Applications

- Substation Automation
- Geographical Information System for Transmission
- Wide Area Measurement System (WAMS)
- Hi-speed information processing
- Advanced protection and control
- Modeling, simulation and visualization tools
- Advanced grid components for transmission
- Advanced regional operational applications

Deeply integrated with AMI, ADO and AAM – ATO optimizes transmission operations

AAM Technologies and Applications

- **Advanced sensors**
  - System Parameters
  - Asset "health"
- **Integration of real time information with other processes:**
  - Operations to optimize asset utilization
  - T&D planning
  - Condition based maintenance
  - Engineering design and construction
  - Customer service
  - Work and resource management
  - Modeling and simulation

Integration of AMI, ADO, and ATO with asset management processes will dramatically improve grid operations and efficiency

Milestone Sequence

AMI and DR

AMI empowers the customer and establishes communications to the loads

Distribution (ADO)

ADO enables self healing

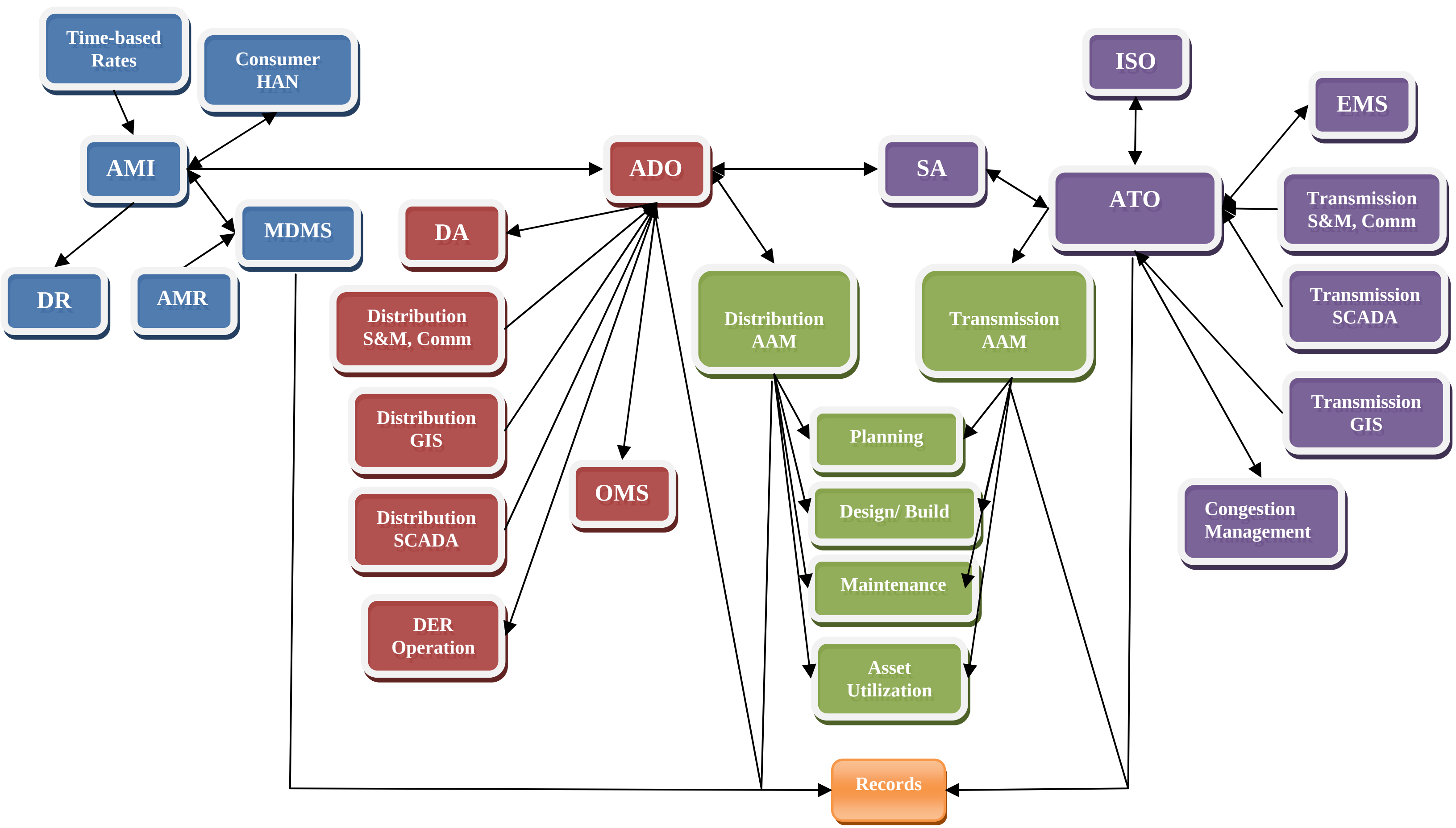
Transmission (ATO)

ATO addresses congestion

Asset Management (AAM)

AAM greatly improves the performance of today’s asset management programs

The “Big Picture”



Why do we need metrics?

- **Keep us on track**
  - Identify successes and opportunities for improvement
  - Initiate Corrective Action to address problems, reinforce good progress
  - Serve as an effective communication tool
  - Create alignment and motivation among stakeholders

- **Enable us to project future progress**
  - Establishes baseline for target setting
  - Provides insights for interdependent efforts
  - Keeps the “end in mind”

Metrics – Work to date

Reliability

- Outage duration and frequency
- Momentary outages
- Power Quality

Security

- Ratio of distributed generation to total generation
- Consumers participating in energy markets

Economics

- Peak and average energy prices by region
- Transmission congestion costs
- Cost of interruptions and power quality disturbances
- Total cost of delivered energy

Metrics – Work to date

Efficient

- System electrical losses
- Peak-to-average load ratio
- Duration congested transmission lines loaded >90%

Environmentally Friendly

- Ratio of renewable generation to total generation
- Emissions per kilowatt-hour delivered

Safety

- Injuries and deaths to workers and public

Smart Grid Workshop in June – Develop metrics for achieving the characteristics

For More Information

- The Modern Grid Strategy
- Smart Grid Newsletter
- EPRI Intelligrid
- Galvin Electricity Initiative
- GridWise Alliance
- GridWise Architecture Council
- European SmartGrid Technology Platform

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